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Gábor Vadas:

### **MODELLING HOUSHOLDS' SAVINGS AND DWELLINGS INVESTMENT – A PORTFOLIO CHOICE APPROACH<sup>1</sup>**

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## **Abstract**

One important characteristic of dwellings is that housing can be regarded as an investment or asset. Our paper focuses on this function of dwellings and develops a stochastic portfolio choice model for the housing market, which is easy to incorporate into medium and large-scale macro models. Theoretical results suggest that house prices move in line with households' income, although house prices have a higher variance than income does. Another important implication of the model is that the portfolio share of housing investment depends on the excess return, defined as the difference between return on housing and financial investment and the variance of excess return describing the riskiness of an asset. Our intention is to test these theoretical implications of the model on several countries, however we only test on UK data, due to the data availability. In this case, empirical results strengthen the model framework.

## **I. Introduction**

Housing market is a frequent topic of discussion among policy-makers and researchers. The most typical issue relates either to the financial sector or to the development of the mortgage loan market with its implications for the financial sector. The main concern is raised by financial sector stability.

The first obvious link between the housing market and financial stability is the level of households' mortgage loans or, in other words, the level of households' indebtedness. The higher the level of indebtedness, the higher the risk of default in the event of a change in mortgage interest rates. This influences the financial position of lenders. The second link is established by changes in house prices. If mortgage repayment is tied to the value of collateral, namely dwellings, changes in house prices alter monthly repayment by changing the risk premium. Increasing house prices reduce, while decreasing house prices increase the risk premium. Thus, changes in house prices either increase or decrease the amount of monthly repayment, thereby influencing the ability to repay, and the possibility of default.

However, the financial sector is not the only one in which interest rates and house prices play a critical role. House prices are also an important factor in households' life and are essential for understanding the housing market. The importance of the housing market may be even more crucial for households than for the financial sector. Dwellings have several functions – it is a roof over your head, a component of households' wealth, a property which can be used as collateral, a potential form of investment or an asset, etc. This paper focuses on the asset function. Its aim is to examine housing theoretically as an investment and develop a model which can handle this kind of investment decision and be a building block of medium or large-scale macro models. The appropriateness of this approach is tested on UK data.

The paper is structured as follows. In Section 2, we overview the related literature of research and show some selected works on modelling household behaviour. In Section 3, we develop a portfolio choice model in a stochastic environment, which can be applied to describe housing investment. Section 4 defines a set of data, while the implication of the model is empirically tested and verified in the Section 5. Section 6 summarises the results and indicates some future work. Finally, appendix displays some estimation problems in accession-countries.

## **II. Related literature**

The importance of the housing market from the perspective of households is unassailable on both the micro and macro levels. However, its mechanism is different from that of the financial sector. First, changes in house prices and the existence of housing wealth influence households' behaviour. On the one hand, a rise in house prices implies increasing wealth, which makes higher consumption possible through the wealth effect. The credit channel has a broadly similar effect. A rise in house prices increases housing wealth and so the available collateral for loan, which, in turn, induces higher consumption expenditure.

On the other hand, we can consider housing investment as any other 'normal' investment. The owner of a house can realise income from tenants and from changes in house prices. Increasing house prices can provide a higher return on real estate than financial investment does, and force households to reallocate their portfolios. Second, focusing on the

macroeconomic view, housing investment amounts to a sizeable share of nation-wide investment expenditure.

Several theoretical and empirical studies seek to incorporate these effects into their models. Westaway (1992) provides a comprehensive general equilibrium model, which incorporates the flow of housing services into the utility function. Aoki *et al* (2001) go one step further and use not only housing services in the utility function, but apply the financial accelerator developed by Bernanke *et al* (2000). The main point of the financial accelerator is that house prices influence housing wealth that households can use as collateral in borrowing. If house prices increase, housing wealth and available collateral do so as well. Consequently, households can borrow at a lower financial premium.

Households' financial accelerator leads us to the empirical approach of the housing wealth effect. The Bank of England (BoE)(2000) model uses the modified version of error correction equation, originally suggested by Hendry and Ungern Sternberg (HUS) (1981)<sup>2</sup>. In the BoE model, households' wealth consists of not only net financial but also housing wealth. One can easily see the similarity between the effect of the financial accelerator and that of incorporating housing wealth into the ECM form. When house prices rise, total housing wealth does so too, which implies a positive adjustment to consumption through the error correction mechanism. Case *et al* (2001) and Girouard and Blöndal (2001) also found empirically significant positive relationship between housing wealth and household expenditure.

Relying on the above-mentioned, one could easily conclude that these empirical models solve the problem entirely. However, we have to admit that, although the influence of housing wealth on consumption has been modelled, we do not know much about the portfolio decisions of households. Nor are we familiar with the factors, which determine housing wealth in the HUS approach, namely the changes in house prices and housing investment. Although the determinants of house price evolution have a long history in empirical literature, these studies generally focus on house prices equation only, hardly taking into consideration its implication to household behaviour or more specifically housing investment (see Chen and Patel (1998), Hsueh (2000)). The BoE model formally contains housing investment whose growth rate has not been modelled, however. Instead, housing investment simply equals the business investment rate thus there is no link between house prices and housing investment.

In the following, we investigate the factors, which influence house prices and households' investment expenditure. Furthermore, we develop a model that can handle this incompleteness and is easy to be incorporated into medium or large-scale macro models.

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<sup>2</sup> The general form of the HUS equation is

$$\Delta c_t = \theta_0 + \theta_1 \Delta y_t - \theta_2 (c_{t-1} - \alpha_1 y_{t-1} - \alpha_2 w_{t-1}) + \varepsilon_t$$

where small letters denote the natural logarithm of consumption ( $c$ ), income ( $y$ ) and wealth ( $w$ ). The variant of the HUS formula is used in the ECB model (see Fagan *et al.* (2001)), and a similar ECM formula can be found in the NIGEM model (see NIESR, Jakab-Kovács (2002)). Muellbauer and Lattimore (1995) also recommend this approach in their empirical studies.

Naturally, the ECM form is not a completely different approach from the general equilibrium model. When there is liquidity constraint, ECM can be derived from utility maximising problem (see Jakab-Vadas(2001) appendix) or minimising a quadratic loss function (see Hendry and Ungern Sternberg(1981)).

### III. The model

Our model is based on a stochastic portfolio choice model of Cochrane(2000). For reasons of tractability, we consider only two types of investment:

- financial investment having  $R_{t+1}^I$  return at  $t+1$  on every invested currency unit in period  $t$ , and
- real estate investment having  $R_{t+1}^H$  payoff at  $t+1$  on every invested unit bought at price  $P$  in period  $t$

The payoff ( $R_{t+1}^H$ ) consists of two components – the price and other income (dividend per unit,  $V$ ) in period  $t+1$ , thus  $R_{t+1}^H = P_{t+1} + V_{t+1}$ . The optimisation problem of households is

$$\begin{aligned} \max_{w_1, w_2} \quad & \sum_{j=0}^{\infty} E_t \left[ \beta^j U(C_{t+j}) \right] \\ \text{s.t.} \quad & C_t + W_t^I + P_t W_t^H = R_t^I W_{t-1}^I + R_t^H W_{t-1}^H + Y_t \end{aligned} \quad (1)$$

where  $C$ ,  $Y$  and  $W$  denote consumption, income and the amount invested in assets, respectively. Solving (1), the first-order condition for an optimal consumption and portfolio choice can be obtained:

$$1 = E \left[ \beta \frac{U'(C_{t+1})}{U'(C_t)} R_{t+1}^I \right] \quad (2)$$

and

$$P_t = E \sum_{j=0}^{\infty} \beta^j \frac{U'(C_{t+j})}{U'(C_t)} V_{t+j} \quad (3)$$

which are well-known asset pricing formulae. Let the first asset be the risk-free asset,  $R_{t+1}^f = R_{t+1}^I$  and let the second be housing investment,  $R_{t+1}^h = R_{t+1}^H$ . Recalling that  $P_{t+1} + V_{t+1} = R_{t+1}^h$  and focusing on time  $t$  and time  $t+1$  period, we get

$$1 = R_{t+1}^f E \left[ \beta \frac{U'(C_{t+1})}{U'(C_t)} \right] \quad (4)$$

and

$$P_t = E \left[ \beta \frac{U'(C_{t+1})}{U'(C_t)} (P_{t+1} + V_{t+1}) \right] = E \left[ \beta \frac{U'(C_{t+1})}{U'(C_t)} R_{t+1}^h \right] \quad (5)$$

from equations (2) and (3).

In the first step in applying the portfolio choice model for housing investment, we should rethink the role of dwellings. Even if housing investment has several special properties, e.g. the requirement of a considerable amount of initial money, large transaction costs, uncertainty about quality, the uniqueness of every unit, relative illiquidity, long implementation time *etc.*, it can be regarded as an investment form.

In the microeconomic sense, a house is not simply a ‘roof over one’s head’. Arrondel and Lefebvre(2001) define the dual attitude of households’ decision on housing: a source of housing services and an asset, *i.e.* housing is taken into consideration in investment decisions. Xiao Di(2001) examines the roles of dwellings in the USA, where one of these treats housing investment as a form of investment competitive vis-à-vis financial investment. In sum, despite the special properties of dwellings, actors are willing to buy or sell assets if such an activity is profitable irrespective of the type of the asset in question.

To take the special characteristics of dwellings into consideration, we define the components of payoff, similar to Cho (1996), Muellbauer and Murphy (1997). Let

$$R_{t+1}^h = [P_{t+1} + V_{t+1}] - [\delta_{t+1} + m_{t+1} + t_{t+1}^p + r_{t+1}^m] \quad (6)$$

where  $R^h$  denotes the payoff on dwelling,  $d$  is the rental fee from tenant,  $\delta$  is depreciation,  $m$  is maintenance cost per unit,  $t^p$  and  $r^m$  are property tax and mortgage interest paid. The first brackets represent the benefit from owning house, while the second brackets represent the cost of asset holding. To keep the equation tractable, let us return to the standard notation of payoff  $R^h$  rather than use this long expression.

One can state that most households are likely to buy a flat in order to live in it rather than sell it afterwards. Moreover, the above mentioned special properties of dwellings rule out that housing can be an asset. Naturally, this argument is valid to a certain extent. It cannot be ruled out that, if the payoff of housing investment is significantly higher than that of other assets, agents are willing to invest in it. As a consequence, payoff affects the demand for dwellings.

Although the demand side is determined, the supply of housing is not modelled explicitly, thus we apply a neutral approach which does not distort our results. In the short run, new housing supply is obviously inelastic, thus increasing demand pushes up house prices. In the long run, the simplest explanations are the perfectly elastic or inelastic supply. The perfectly elastic supply can be ruled out, since housing construction uses a completely constrained resource, *i.e.* land. The inelastic supply also cannot be maintained, given that the number of dwellings is rising in cities. A plausible approach is that the new housing supply equals the growth rate of population in the long run.

To understand how our model works, let us assume that income and preferences are unchanged and the housing market is at its long-run equilibrium, so that house prices are constant and housing starts are equal to growth in population. Assume an unexpected rise in

income, which, in turn, increases the demand for new residence. This leads to an increase in house prices, additional new construction occurs and the city grows in size. At a new equilibrium, the city is physically larger, house prices remain constant at a higher level and housing starts are equal to the long-run steady-state rate again. In this case, house prices will increase in line with income.

To put differently, suppose that the housing market was in steady state, which means the return on housing and other forms of investment are equal. When house prices increase, *ceteris paribus*, the return on housing increases relative to other asset types, which, in turn, encourages builders to step up production (i.e. to invest more). This intuition is in line with Mayer and Somerville's (1996). They argue that house prices are a stock variable equilibrating the quantity of housing with total demand. Housing starts (which is a new housing supply) are a flow variable, representing changes in the stock of housing, thus housing starts are a function of other flow variables, such as changes in house price.

To formalise this intuition between income and house prices as well as between house prices and dwellings investment, we apply widely used CES utility function:

$$U(C_t) = \frac{1}{1-\gamma} C_t^{1-\gamma}$$

Substituting the utility function into equation (5) and assuming that rental fee moves in line with house prices<sup>3</sup>, namely  $V_t = \varphi P_t$ , so that housing prices are the determinant of dwelling investment payoff and rearranging the equation we obtain an equation which describes the link between consumption and house prices

$$1 = E \left[ \beta \left( \frac{1}{\Delta c_{t+1}} \right)^\gamma (1 + \varphi) \Delta p_{t+1} \right] \quad (7)$$

where small letters denote the logarithm of variables. Assume  $\gamma \rightarrow 1$ , i.e. the utility function is logarithmic. Knowing that households adjust consumption to their permanent income, which is approximated by current income, we get

$$1 = E \left[ \beta \frac{1}{\Delta y_{t+1}} (1 + \varphi) \Delta p_{t+1} \right] \quad (8)$$

Equations (7) and (8) provide some important results of the model. First,  $\Delta p_t$  is proportional to  $\Delta y_t$ , implying co-movement between house prices and income in the long run, which can be captured empirically by an error correction model. Furthermore, if  $\gamma \rightarrow 1$ , the degree of homogeneity equals one. These theoretical results support several empirical studies where the relationship between house prices and income is described in this manner (see Cho (1996), Muellbauer and Murphy (1997), Malpezzi (1998) and the BoE model (2000)). Equation (7)

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<sup>3</sup> This assumption is supported by our data. For more details, see the data section.



underpins Pain and Westaway's (1994, 1996) approach theoretically, since in their paper housing demand is conditioned on consumer expenditure, and not on disposable income. The disequilibrium between housing demand and supply influences house prices. Pain and Westaway argue that conditioning on consumption ensures that a permanent income measure used in determining the level of consumption is consistently reflected in housing demand.

Second, the variance of house prices cannot be less than that of income. If  $\frac{1}{\beta} \frac{1}{1+\varphi} > 1$ ,  $\Delta p$  has higher variance than  $\Delta y$  does, which is true for any reasonable parameter value. As a consequence, the size of difference in variance depends on the value of  $\beta$  and  $\varphi$ , or rather, the ratio of house price volatility to income volatility<sup>4</sup> equals  $[\beta(1+\varphi)]^{-1}$ .

In the next step, we derive the portfolio share of two assets<sup>5</sup>. For a more convenient notation, let  $D_{t+1}$  denote the stochastic discount factor and define the payoff of housing investment as in equation (7):

$$D_{t+1} = \beta \frac{U'(C_{t+1})}{U'(C_t)}, \quad R_{t+1}^h = (1+\varphi)P_{t+1}/P_t$$

Equation (5) has the following form:

$$1 = E[D_{t+1} R_{t+1}^h] \quad (9)$$

As  $E[xy] = E[x]E[y] + \text{cov}(x, y)$ , equation (9) can be rewritten as

$$1 = E[D_{t+1}]E[R_{t+1}^h] + \text{cov}[D_{t+1}, R_{t+1}^h] \quad (10)$$

It follows from equation (4) that  $E[D_{t+1}] = 1/R^f$ , thus

$$E[R_{t+1}^h] = R_{t+1}^f [1 - \text{cov}(D_{t+1}, R_{t+1}^h)] \quad (11)$$

Substitute the form of stochastic discount factor back

$$E[R_{t+1}^h] = R_{t+1}^f \left[ 1 - \beta \frac{\text{cov}(U'(C_{t+1}), R_{t+1}^h)}{U'(C_t)} \right] \quad (12)$$

and the second period constraint yields

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<sup>4</sup> The inference is even more obvious if equation (8) is re-arranged in deterministic case to obtain the following form  $\Delta p_{t+1} = \frac{1}{\beta(1+\varphi)} \Delta y_{t+1}$

<sup>5</sup> This is where the main difference between the deterministic and stochastic case lies. In the deterministic case, the arbitrage condition between assets determinates the entire amount of the money invested only, but it cannot determine the portfolio shares.

$$E[R_{t+1}^h] = R_{t+1}^f \left[ 1 - \beta \frac{\text{cov}(U'(Y_{t+1} + R_{t+1}^f W_t^f + R_{t+1}^h W_t^h), R_{t+1}^h)}{U'(C_t)} \right] \quad (13)$$

It is easy to see how equation (13) determines the portfolio shares of different assets. Given a risk-free interest rate and the payoff of the second asset (in our case, housing investment), households have to set the amount of assets in such a way to equalise the above equation through the covariance term. It should be noted that the value of covariance is not independent of the amount of assets. When the  $R_{t+1}^h$  covaries positively with consumption and thus negatively with  $U'(C)$ , households require higher expected return relative to risk-free rates. When the  $R_{t+1}^2$  covaries negatively with consumption and thus positively with  $U'(C)$ , households are satisfied with lower expected return relative to risk-free rates (e.g. insurance).

The other aspect of equation (13) explains how house prices determine the invested amount. When house prices covary positively with consumption and the return on housing investment increases, then, for the equality of equation (13) to be held, the value of right squared bracket has to increase. Since house prices covary negatively<sup>6</sup> with  $U'(C)$ , the value of  $\text{cov}(\cdot)$  has to increase, which is the case when housing investment increases<sup>7</sup>. For a more detailed view, we rearrange equation (12) as

$$E[R_{t+1}^h] - R_{t+1}^f = -\beta \frac{\text{cov}(U'(Y_{t+1} + R_{t+1}^f W_t^f + R_{t+1}^h W_t^h), R_{t+1}^f)}{(R_{t+1}^f)^{-1}} \quad (14)$$

Note that the variance of the consumption period  $t+1$  depends on the variance of the risky-asset payoff at  $t+1$  if the only source of uncertainty is the return of this asset. Assume that the risky-asset payoff is normally distributed, thus consumption growth also follows normal distribution. Using that  $R_{t+1}^f = \beta E_t[(C_{t+1}/C_t)^\gamma]$  and  $E[e^z] = e^{E[z] + \frac{1}{2}\sigma^2(z)}$  if  $z$  is normally distributed yields

$$E[R_{t+1}^f] = \exp\left(\ln \beta + \gamma E[\Delta c_{t+1}] + \frac{\gamma^2}{2} \sigma^2 \Delta c_{t+1}\right) \quad (15)$$

where  $\sigma^2$  is the variance of the risky asset. Substituting equation (15) into (14), we obtain

$$E[R_{t+1}^h] - R_{t+1}^f = -\beta \frac{\text{cov}(U'(Y_{t+1} + R_{t+1}^f W_t^f + R_{t+1}^h W_t^h), R_{t+1}^h)}{\exp(-\ln \beta - \gamma E[\Delta c_{t+1}] - \gamma^2 \sigma^2 \Delta c_{t+1}/2)} \quad (16)$$

Equation (16) provides a richer explanation for portfolio choice. The left-hand side of equation (16) defines the excess return, which is equal to the risk adjustment. Note that the

<sup>6</sup> See the section on the excess return of empirical results.

<sup>7</sup> Numerous studies assume the same characteristic housing investment function in an exogenous way, and simply integrate it into the models which they use. Porteba (1984) assumes that  $I = f(P)$ , where  $I$  and  $P$  denote housing investment and house prices, respectively. Since his model is deterministic, the arbitrage condition cannot determinate portfolio shares (See Footnote 5), thus an exogenous investment function is necessary in order that the amount of housing investment can be derived.

structure of the optimal portfolio depends not only on the size of payoff, but also on the riskiness (variance) of payoff. First, the mechanism of return is the same as the one mentioned above. When the payoff of the asset covaries positively with consumption, it must promise a higher expected return than risk-free rates do, in which case the excess return is positive. In that case, the asset has to offer a higher expected return, i.e. a higher excess return to induce investors to hold more of this asset. Second, the riskiness and the amount invested into risky asset depend inversely, i.e. higher risks *ceteris paribus* reduce the share of risky asset. On the basis of equation (16), increasing variance reduces the value of the denominator. So, for the equality to be held, the nominator has to decrease. Since the return is unchanged, the covariance might be lower if the amount invested in increasing riskiness asset is lower. In the section on empirical results, we examine whether the above assumption and properties can be underpinned by empirical evidence.

#### IV. Data

For the purposes of empirical examination, we test the model for the UK housing market. Two data sets are used: the annual house prices and disposable income figures available from 1948. House prices are published by National Statistics of UK in the following structure:

- 1946 to 1952: a house price index for modern, existing dwellings was calculated by the Co-operative Building Society from 1946 (=100) to 1970. The movements in the index from 1946 to 1953 have been applied to the average 1953 price, in order to impute average prices for 1946-1952.
- 1953 to 1955 derived from the average of two series of UK projected house prices.
- From 1956 to 1965 prices are based on the BS4 survey of mortgage completions for new dwellings. No adjustment has been made to allow for the absence of existing dwellings. Whilst in recent years average prices of new dwellings have often been more than 10 per cent higher than the average for all dwellings, this was not the situation from 1966 to 1974, the first years when BS4 data both for new and all dwellings were available.
- From 1966 to 1992, average prices are based on the 5 per cent survey of building societies. From 1969, the mix-adjusted index is also based on the survey of building societies.
- From 1993 to date, average prices and the mix-adjusted index are based on the five per cent Survey of Mortgage Lenders.

Second, we use quarterly data sets (disposable income, house prices, net financial saving and dwellings investment) from 1984 Q1 because housing investment data are available from that time. The yearly data set is used parallel to quarterly data to estimate house price equations.

Rental fees are available from 1992 at Housing Finance Review published by the Centre for Housing Policy. We found that the ratio of rental fee to house price is quite stable, thus rental fee before 1992 is computed as the constant share of house prices.

The above data can be understood and measured more easily than housing investment. Housing investment on the micro level is different from housing investment on the macroeconomic one. While each house purchase is investment in the micro-economic sense, this is not true macro-economically. It should be noted that, when a household buys a second-hand flat from another household, though this is dwelling investment on the household level, it does not appear so on the aggregate household level. Briefly, only the first sale of dwellings is considered as housing investment in the macro-economic sense. In other words, dwelling

investment of the household sector equals new housing supply, for which data are available in national statistics.

The time series, where necessary, are seasonally adjusted.

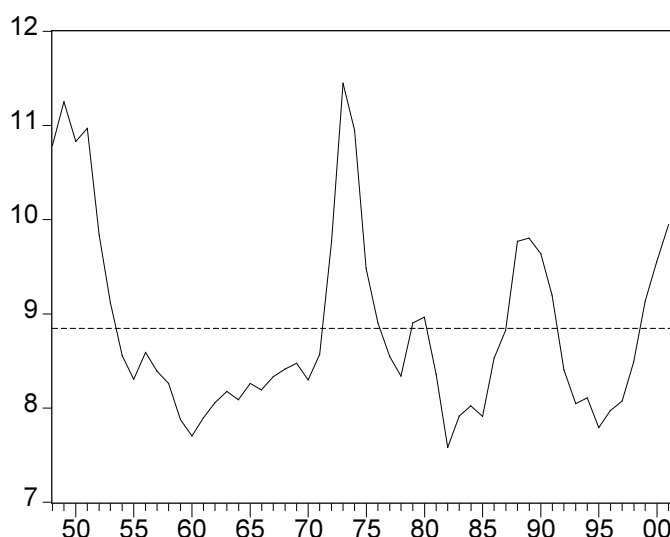
## V. Empirical results

To evaluate its theoretical implications, we examine empirically the two main suggestions of the model. First, whether the house prices move together with income (see equation (8)) and whether the error correction approach of house prices and income dynamics is appropriate. Second, whether the excess return and riskiness can determinate the portfolio choice between assets and, if so, in what way. For the sake of tractability we concentrate only on two aggregated assets: net financial savings and housing investment and their development.

### V.1 House price

Equation (8) states that house prices and income move together in the long term and house prices have higher volatility. Due to the longer implementation time of house building and the higher volatility of house prices compared to income, house prices start to rise more strongly than income in the short term. When new buildings are completed, causing housing supply to increase, house prices decrease and the ratio of house prices to income returns to its steady-state value. Chart 1 displays the ratio of house prices to income per capita, which seems to fluctuate around a stable value in the UK.

Chart 1 Ratio of house price to income



Ratio of nominal house prices to nominal disposable income per capita in the UK from 1948.

The charts do not reject our hypothesis about the stable house prices to income ratio. For a more robust inference, we have annexed in Chart 7 house price per income ratios in other countries. According to the charts, there are several countries where the stable relationship between house prices and income per capita also can be held. Of course, there can be bubbles

and deviations in the short term. The above-mentioned fact implies the applicability of error correction models, where we are able to formalise long-term restrictions allowing short-term dynamics and use econometric tests to verify this question empirically. The estimated framework is the following:

$$\Delta p_t = \gamma_1 + \gamma_2(p_{t-1} + \alpha_1 - \alpha_2 y_{t-1}) + \sum_{i=3}^4 \gamma_i \Delta p_{t-(i-2)} + \gamma_5 \Delta y_t \quad (17)$$

where  $p$  is the log of house price per square metre. Since the UK time series is long enough, we apply richer short-run dynamic and estimate the long and short-run parameters in the same step by NLS (in this case  $\alpha_l = 0$ , because equation (17) has an other constant,  $\gamma_l$ ).

For the sake of obtaining robust results, the estimation of UK parameters has been performed on both yearly data from 1948 and quarterly data from 1984 Q1. The upper section of Table 1 displays the estimated parameters of the unrestricted house price equation. A glance at the statistics in equation (17) seems to be appropriate. All of the parameters are different from zero at standard significance levels<sup>8</sup>. The first important thing is whether the stability of the house price ratio to income or, econometrically, the  $[1 \ -1]$  cointegration vector is an acceptable assumption<sup>9</sup>. This assumption implies the long-run homogeneity between house prices and income, *i.e.* the  $\alpha_2$  parameter should be equal to 1. According to the Wald test, the restriction that  $\alpha_2$  equals 1 cannot be rejected for either the yearly or the quarterly data.

In addition to the long-run homogeneity assumption, we test an additional restriction. To get a correct steady ratio, we should examine whether the sum of short-run parameters equals one. If we ignore this, the short-run dynamics bias the long-run equilibrium (see Appendix A.2). In our case,  $\gamma_3 + \gamma_4 + \gamma_5 = 1$  is the testable restriction, which means that the sum of the estimated parameters of lagged values of house price and income growth should be equal to one. The Wald test accepts this restriction (the  $p$  value of Wald test is 0.67 and 0.28 in UK quarterly and yearly models respectively). Thus we have restricted the parameter and re-estimated equation (17).

The new estimated parameters are shown in the bottom section of Table 1. According to the test statistics, the restricted version of equation (17) is an acceptable representation of house price movements. Consequently, these empirical results underpin the co-movement of house prices and income derived from our model.

Another testable implication of the model is related to the variance of house prices and income. Empirical tests underpin equation (8), which implies that the growth rate of house prices has higher variance than income has. Based on Table 2, this hypothesis can be held in the sample period.

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<sup>8</sup> Except  $\gamma_l$  and  $\gamma_5$  in yearly UK model.  $\gamma_l$  is the constant in the regression, so it is not important and  $\gamma_5$  will be acceptable after restriction. See more details later.

<sup>9</sup> To test correctly the cointegration assumption, we examined the residuum of  $ph_t = \alpha_l + \alpha_2 y_t$  equation when  $\alpha_2$  is estimated and  $\alpha_l$  are restricted to one. According to the ADF and PP unit root tests, the residuum is stationary in both case.

## V.2 Excess return

One can see in the stochastic case how excess return and the riskiness of assets determine the portfolio choice. Investors invest more in assets if its payoff (or, equivalently, excess return) increases, provided positive covariance between return and consumption, and invest less if the volatility of expected return rises. Thus, our special interest is in the excess return ( $ER$ ) on holding real estate above financial assets.

Equation (6) describes the components of return on real estate; however, we apply an empirical approximation of the excess return<sup>10</sup>:

$$ER_t = \frac{P_t + V_t}{P_{t-1}} - r_{t,3} \quad (18)$$

where  $P$ ,  $V$  and  $r_3$  denote the house price per square meter, rental fee and yield on three-month risk-free bond respectively. Since the return on real asset is defined between  $t+1$  and  $t$ , that is why we apply the three-month bond. Let  $\tau$  denote the ratio between dwelling and financial investment:

$$\tau = \frac{HI_t}{HI_t + NFS_t} \quad (19)$$

where  $HI$  is housing investment and  $NFS$  is net financial savings. Chart 2 displays historic values of the excess return and  $\tau$ .

As mentioned earlier, there is a positive relationship between the portfolio share of housing investment and the return on it, if consumption and return or, more specifically, house prices covary positively. Since both consumption and house prices are not stationary in level (as they increase continuously), we compute the covariance of their growth rates. To be able to evaluate the size of the relationship, we present the correlation rather than the covariance:

$$\begin{aligned} cor(\Delta p_y^{UK}, \Delta c_y^{UK}) &= 0.55 \\ cor(\Delta p_q^{UK}, \Delta c_q^{UK}) &= 0.49 \end{aligned}$$

where the subscripts denote yearly and quarterly data. The covariance is positive and significant on yearly and quarterly UK data, suggesting that a higher return on dwelling investment implies a higher portfolio share of housing.

Since return on housing covaries positively with consumption, equation (13) implies that households require a higher return on this asset, thus the excess return has to be positive. According to the test statistics, the sample mean of excess return is positive and differs significantly from zero<sup>11</sup>.

In addition to the covariance analysis, Chart 2 provides some results in respect of households' portfolio decisions between financial and dwelling investments or, in other words, the ratio of housing investment to gross savings. (Note that gross saving is the difference between

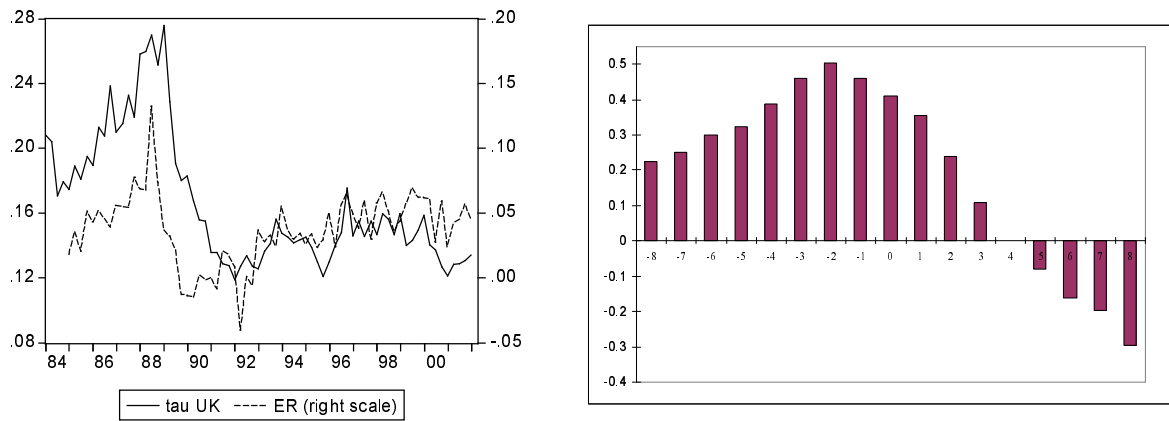
<sup>10</sup> Aoki *et al* (2001) also define the expected gross return on housing in a similar way.

<sup>11</sup>  $H_0: Mean(ER) = 0$ ,  $t$ -statistic = 11.35, probability of  $H_0 = 0.00$ .

disposable income and consumption expenditure *id est*. households' funds available for investment). The left panel of Chart 2 shows the co-movement of excess return and the dwelling investment rate. Due to the long construction time, we expect leading property of excess return compared to the investment rate. This intuition is supported by the cross-correlation coefficient.

The diagram at the right panel of Chart 2 displays the cross-correlation coefficients as a function of  $i$ , where  $i$  denotes the leading or lagging periods of excess return. Negative  $i$  means that the excess return leads the housing investment rate, while positive  $i$  implies that the excess return lags compared to the housing investment rate. The chart confirms our intuition. The high cross-correlation coefficients at  $i = -1$  and  $-2$  (0.46 and 0.50 respectively) mean that changes in the excess return lead the changes in the investment ratio. This result is corroborated by the Granger causality test (see Table 4) with a slight difference. Based on the cross-correlation, coefficients from  $i = -1$  to  $-6$  lead seem to be appropriate, while the Granger test (see Table 4) shows the only one period lead property compared to the lag values of excess return.

**Chart 2 The ratio of housing investment to gross savings and excess return**



Left panel:  $\tau$  is the rate of housing investment in relation to gross savings (financial savings plus dwelling investment),  $ER$  is the excess return. The right panel shows the cross-correlation between the rate of housing investment to gross savings and the excess return, exactly the  $f(i) = \text{Corr}(\tau, ER(i))$  function.

In fact, not only the return on investment, but the variance of yield as well, is an important factor in investment decisions. If investors are risk averse, they will prefer an asset with lower volatility in their choice between two assets with the same return. In our case this means that, if there are stronger-than-usual fluctuations in the excess return around its expected value, this will discourage investors from investing in dwellings<sup>12</sup>. We proxy the riskiness of real estate investment by the square of excess return minus the sample average of excess return.

We expect that the higher risk, i.e. the higher value of adjusted excess return squared, will reduce the attractiveness of real estate, causing the share of dwelling investment to decline within gross savings. Table 5 comprises the results of the Granger causality test, suggesting

<sup>12</sup> Owing to the fact that the real interest rate is smoother than changes in house prices, the volatility of excess return is driven by house price fluctuation. In the UK sample, the variance of growth rate of real house prices is higher than that of yield on three-month risk-free bonds, and tests have rejected the hypothesis that the variance of these two series is equal (See Table 3).

that three-quarter or more lead the squared excess return help to explain the ratio of dwelling investment to gross savings.

### *Estimation results*

Based on the cross-correlation coefficient and the Granger causality test and in order to get an econometrically correct residuum<sup>13</sup>, we use the following equation to explain the ratio of housing investment to gross savings:

$$\tau_t^{UK} = \eta_1 + \eta_2 \tau_{t-1}^{UK} + \eta_3 \tau_{t-2}^{UK} + \eta_4 ER_{t-1} + \eta_5 (ER_{t-4} - \overline{ER})^2 \quad (20)$$

Although equation (20) is easy to interpret, the problem we are facing is that the ratio of housing investment to gross savings must be between 0 and 1. The linear model cannot assure the fulfilment of constraint, which causes serious problems in integrating this block into a larger model. The values of the  $(1+e^{-x})^{-1}$  logistic function are between 0 and 1, thus the function form seems to be appropriate<sup>14</sup>:

$$\tau_t^{UK} = \frac{1}{1 + \exp\left[-(\eta_1 + \eta_2 \tau_{t-1}^{UK} + \eta_3 \tau_{t-2}^{UK} + \eta_4 ER_{t-1} + \eta_5 (ER_{t-4} - \overline{ER})^2)\right]} \quad (21)$$

Both equations (20) and (21) provide similar results (See Table 7 and Chart 3). As expected, the estimated sign of  $\eta_4$  is positive, implying that increasing house prices yield a higher housing investment ratio and, consequently, higher housing investment. The estimated  $\eta_5$  is negative, implying that higher risk in real estate investment discourages investors from making housing investment, which, in turn, reduces the ratio of dwellings to gross savings.

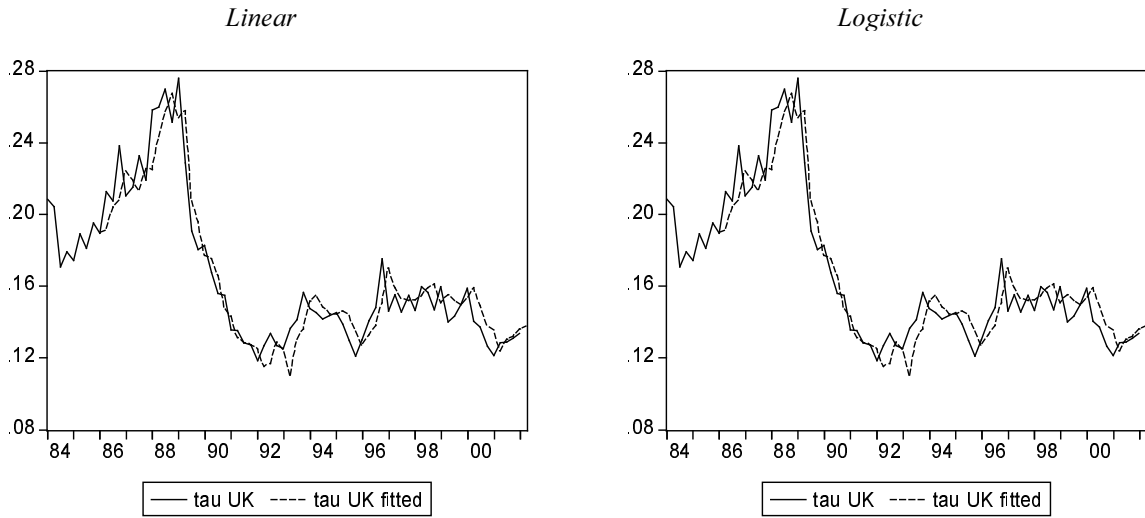
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<sup>13</sup> We tested different specifications. Although the parameters were significant, not all the residuum tests were acceptable in these cases, so we chose the ones that were the best econometrically.

<sup>14</sup> If  $x \rightarrow \infty$  then  $(1+e^{-x})^{-1} \rightarrow 1$  and if  $x \rightarrow -\infty$  then  $(1+e^{-x})^{-1} \rightarrow 0$ .



**Chart 3 Fitted value of the ratio of housing investment to gross savings in the UK**



$\tau$  is the rate of housing investment to gross savings. The left panel displays the fitted housing investment ratio of the linear model. The right one displays that of the logistic model.

Chart 3 displays the fitted value of the ratio of housing investment to gross savings. So as to measure the additional explanatory power of excess return over the auto-regressive structure, we compare the increment in adjusted  $R^2$ . Restricting the  $\eta_4$  and  $\eta_5$  to 0 and estimating equation (20) we find that the adjusted  $R^2$  is 0.86. When excess return and its variance are used as explanatory variables in the estimation, the adjusted  $R^2$  increases to 0.89.

## VI. Summary and future research

In this paper, we outlined an easily applicable micro-based model, which explains households' portfolio decisions in a stochastic environment. The model has several implications for households' behaviour. First, we found that house prices move in line with households' income. Second, house prices have higher volatility than income does. Third, the effect of expected return and the riskiness of an asset on portfolio choice depends on the covariance between consumption and expected return. If the return on an asset covaries positively with consumption, households expect a higher return on this asset. In addition, increasing expected return implies higher investment, whereas increasing riskiness results in more modest investment in this type of asset.

Although dwellings have several special characteristics, housing investment can be considered as a component of portfolio choice and we applied the changes in house prices as the main determinant of return on it. To test the implications of the model, we used UK data. First, we found that the ratio of house prices to disposable income has displayed a stable value in the past and empirical tests in the error correction model also accept the hypothesis that house prices and income are closely related. Second, we found a positive correlation between UK house prices and consumption, which implies a positive connection between higher excess return on dwellings and housing investment. The cross-correlation coefficient and the Granger causality tests suggest leading property of excess return related to housing investment, which can be explained by the long implementation time of house construction. Regressing the ratio of housing investment to gross savings on leads of excess return and the

volatility of excess return, we found positive coefficients on the excess return and negative ones on volatility. These results empirically underpin our expectations based on the theoretical model.

We plan to test this framework empirically on both developed and accession-country data. The envisaged empirical results will answer the question of to what extent our theoretical model can explain the common behaviour in the housing market and varies from country to country (see Chart 7). An additional problem will crop up in accession countries, where time series are quite short or non-existent. Short data periods combined with a changing system of housing subsidies and an erratic market system make it difficult to disentangle long-term effects generated by fundamental factors from other short-term deviations (see Appendix *A.1*). To increase the reliability of inference in these countries, the panel estimation technique should be applied.

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## Appendix

### *A.1 Estimation difficulties in Hungary*

In order to describe potential difficulties in accession countries, let us examine the Hungarian housing market. First of all, the availability, frequency and quality of time series in Hungary are not adequate in each case. Data on disposable income and dwelling investment are published on a yearly basis by the Hungarian Central Statistical Office. We only have partial information on quarterly dynamics generated by wages and salaries, consumption and net financial savings. Using this set of information, quarterly disposable income and housing investment are estimated. Hungarian house prices represent the most problematic time series, so we have to use two different sources:

- data from GKI surveys for the period between 1995 and 1997<sup>15</sup>,
- data published by the Hungarian Central Statistical Office for the period between 1998 and 2000<sup>16</sup>.

Unfortunately, house price time series are only available on a yearly basis, so they have to be converted at a quarterly frequency<sup>17</sup>.

Another problem is that it is hard to disentangle the different effects on the Hungarian housing market. On the one hand, households lost considerable wealth due to decreasing equity prices caused by the Russian crisis. As a consequence, households reallocated their portfolios, which was likely to influence the real estate market.

On the other hand, the Hungarian government made certain decisions whose effects also distorted housing market developments. First, access to mortgage loans has been easing since 1999 by the government subsidising mortgage interest rates and extending the circle whom is entitled to claim for subsidy. Second, a part of general turnover tax has been refunded since 1999, which is likely to encourage housing investment to be postponed from 1998 to 1999.

Based on the above mentioned, it is not obvious to what extent the house price boom in 1999 was caused by portfolio reallocation, government decisions or income movement. So we have to be careful in interpreting the results. However, as in the UK<sup>18</sup>, the ratio of house prices in Hungary to income per capita also seems to fluctuate around at a stable value (see Chart 4).

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<sup>15</sup> GKI Economic Research (2000).

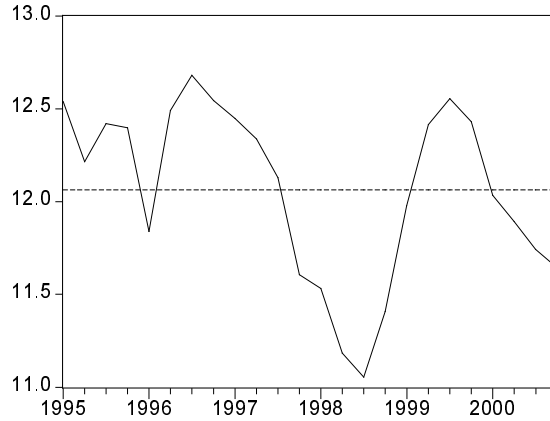
<sup>16</sup> Hungarian Central Statistical Office (1999, 2000)

<sup>17</sup> This conversion is based on the following optimisation method:

$$\begin{aligned} \sum_j (P_j - P_{j-1})^2 &\rightarrow \min, \text{ where } j \in (1995 \text{ Q1}, 1995 \text{ Q2}, \dots) \\ \text{s.t.} \\ PH_Y &= \left( \sum_Q P_{Y,Q} \right) / 4, \text{ where } Y \in (1995, 1996, \dots) \text{ and } Q \in (Q1, Q2, Q3, Q4). \end{aligned}$$

<sup>18</sup> See Chart 1.

**Chart 4 Ratio of house prices to income**



Ratio of house prices to annualised disposable income per capita in Hungary.

Equation (8) and the charts suggest the application of the standard error correction method, and imply the following framework:

$$\Delta p_t = \gamma_1 + \gamma_2(p_{t-1} + \alpha_1 - \alpha_2 y_{t-1}) + \gamma_3 \Delta p_{t-1} + \gamma_4 \Delta y_t \quad (22)$$

where  $p$  is the log of house prices per square metre. Because of the short sample period in Hungary, the ECM form is estimated by two steps Engel-Granger method using OLS. Moreover, based on UK results, we arbitrarily restrict  $\alpha_2$  to 1 in the Hungarian equation and only estimate the equilibrium house price to income ratio ( $\alpha_1$ ) and short-run parameters. The unbiased steady-state ratio requires additional restrictions on short-run parameters, namely  $\gamma_3 + \gamma_4 = 1$ . The Wald test accepts this restriction (the  $p$  value of the Wald test is 0.86 in Hungary), thus we restricted the parameter and re-estimated equation (22). The re-estimated parameters are shown at the bottom of Table 1. According to test statistics, the restricted version of equation (22) is an acceptable representation of house price movement.

Next, we estimate the relationship between excess return and the portfolio share of housing investment. Unfortunately, data on rental fees are not available in Hungary, thus the excess return is computed in a simplified way compared to the UK case:

$$ER_t^{HU} = \frac{P_t}{P_{t-1}} - r_{t,3} \quad (23)$$

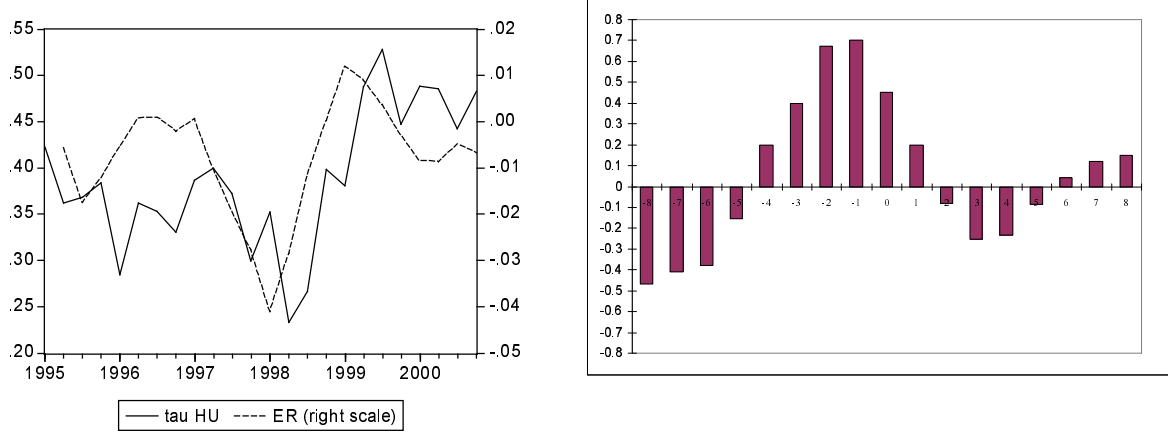
The positive relationship between the portfolio share of housing investment and return on it assumes that consumption and return or, more specifically, house prices covary positively. The covariance is negative but it is insignificant with regard to Hungarian data<sup>19</sup> so nothing conclusive can be stated of Hungary on the basis of the covariance analysis.

In addition to the covariance analysis, Chart 5 provides considerable results in respect of the issue of households' portfolio decisions in Hungary. The left panel of Chart 5 shows the co-movement of excess return and dwelling investment rates, whereas the right panel of Chart 5

<sup>19</sup>  $cor(\Delta ph_q^{HU}, \Delta C_q^{HU}) = -0.14$  where subscripts denote quarterly data.

displays cross-correlation coefficients. We get high cross-correlation coefficients at  $i = -1$  and  $-2$  (0.7 and 0.64 respectively), which means that changes in the excess return lead the changes in the investment ratio. The Granger causality test (see Table 6) also indicates leading property; however, cross-correlation coefficients are not significant at longer leads than 2 periods, while the Granger test shows significant effects up to 5 periods' lead.

**Chart 5 Ratio of housing investment to gross savings and excess return**



Left panel:  $\tau$  is the rate of housing investment to gross savings (financial savings plus dwellings investment),  $ER$  is the excess return. The right panel shows the cross-correlation between the rate of housing investment to gross savings and excess return, exactly the  $f(i) = \text{Corr}(\tau, ER(i))$  function.

Before regressing the housing investment rate on excess return, it seems to appropriate to remove the discretionary decisions of government. First, the easing access to mortgage since 1999 can be grabbed by a dummy variable with a value of 0 before 1999 and 1 after 1999 ( $D99$ ). Second, there may be the slip between the two years caused by general turnover tax refunds so we apply a dummy variable whose value is  $-1$  in 1998,  $1$  in 1999 and  $0$  otherwise ( $D98\_99$ ). The left panel of Chart 6 displays the estimation result when the regression contains only these dummy variables<sup>20</sup> (the adjusted  $R^2$  is 0.56, for its importance, see later). In the next step, we incorporate the excess return into the regression. According to the cross-correlation and the Granger causality test, the squared excess return as a measure of the risk involved in housing investment is acceptable, as in the UK equation. However, we ignore this variable because of the small sample period. The reason why we apply only two-period leads is to save degree of freedom. However, the Granger causality test suggests a higher lead structure than cross-correlation results do.

As in the case of the UK, we estimate both linear and logistic forms, namely:

$$\tau_t^{HU} = \eta_1 + \eta_2 ER_{t-1} + \eta_3 ER_{t-2} + \eta_4 D99 + \eta_5 D98\_99 \quad (24)$$

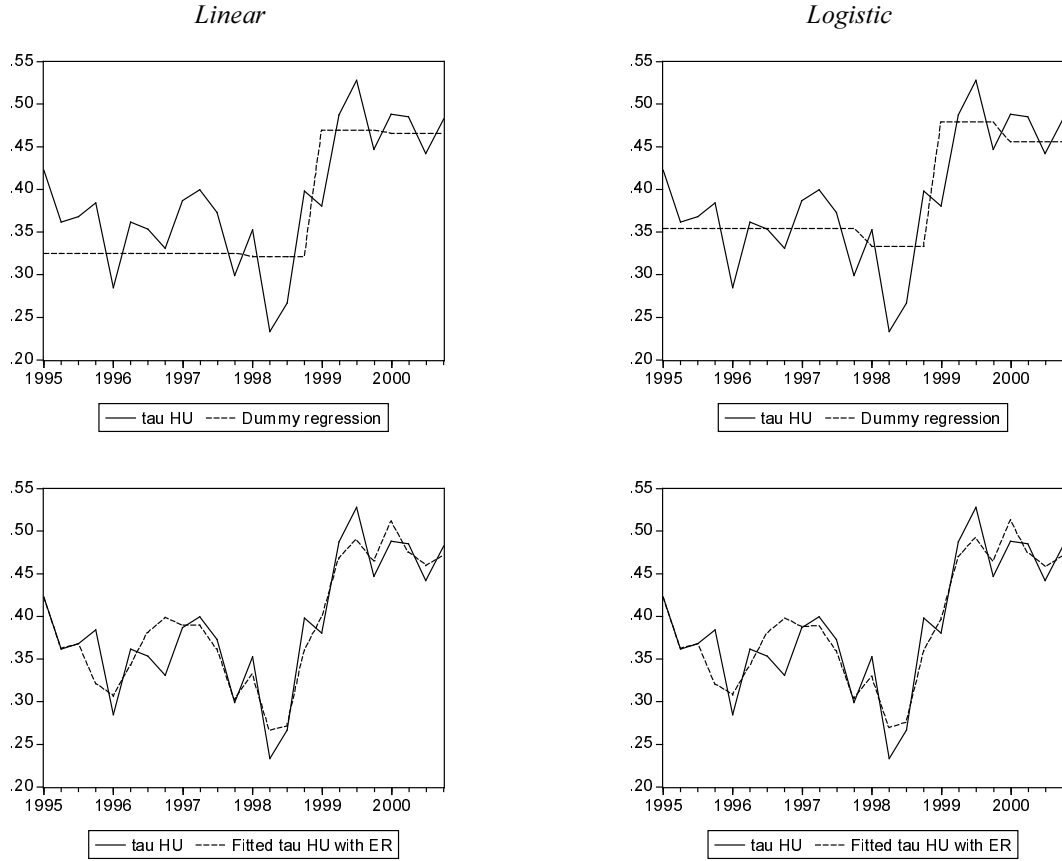
and

<sup>20</sup> Empirical experience is in line with Valkovszky's (2000) expectations, namely the expanded government subsidy can reduce financial saving rate and increase house prices. Further facts about the Hungarian housing market can be found in Kiss (2002).

$$\tau_t^{HU} = \frac{1}{1 + \exp[-(\eta_1 + \eta_2 ER_{t-1} + \eta_3 ER_{t-2} + \eta_4 D99 + \eta_5 D98\_99)]} \quad (25)$$

Table 8 comprises the estimation results. All the estimated parameters are significant and have the expected sign. Chart 6 points to little difference in the fitted models. Naturally, we know that a difference in models is important from the perspectives of stability and forecasting.

**Chart 6 Dummies and fitted value of the ratio of housing investment to gross savings in Hungary**



$\tau$  is the rate of housing investment to gross savings. The left panel displays the fitted housing investment ratio of the linear model. The right panel displays that of the logistic one.

In order to evaluate the high  $R^2$  correctly, we should examine the additional explanatory power of excess return relative to the pure dummy case. The adjusted  $R^2$  increased from 0.56 to 0.83, so we can conclude that the excess return is an important factor in the explanation for households' portfolio decisions, which is obvious to look at the fitted value of regression (See the bottom panels of Chart 6).

These preliminary results must be interpreted with care. The time series is quite short and quarterly Hungarian house prices are derived from yearly data. The panel technique will be able to increase the robustness of the empirical results of accession countries.



## A.2 Parameter restriction in VECM

Consider the following arbitrary VAR for  $p$  lags on the vector of  $N$  variables  $\mathbf{z}_t$

$$\mathbf{z}_t = \sum_{k=1}^p \mathbf{D}_k \mathbf{z}_{t-k} + \delta + \varepsilon_t \quad \varepsilon_t \sim IN_N(\mathbf{0}, \Sigma) \quad (26)$$

$\mathbf{D}_j$  is an  $N \times N$  matrix.  $\delta$  is  $N \times 1$  intercept vector and  $\varepsilon_t$  is a vector of errors with zero mean and constant covariance matrix  $\Sigma$ . Independently of whether the variable  $\mathbf{z}_t$  is  $I(0)$  or  $I(1)$ , the VAR in equation (26) can be reparameterised as a VECM (see Johansen (1988, 1992 and Hendry (1995))

$$\Delta \mathbf{z}_t = \sum_{k=1}^{p-1} \Gamma_k \Delta \mathbf{z}_{t-k} + \Pi \mathbf{z}_{t-1} + \delta + \varepsilon_t \quad \varepsilon_t \sim IN_N(\mathbf{0}, \Sigma) \quad (27)$$

where  $\Gamma_k = -\sum_{i=j+1}^p \mathbf{D}_i$  ( $j \in (1, 2, \dots, p-1)$ ) is  $N \times N$  matrix of short-run parameters,  $\Pi = -(\mathbf{I}_N - \sum_{i=1}^p \mathbf{D}_i)$  is  $N \times N$  matrix of long-run parameters. Although equations (26) and (27) are equivalent of each other, equation (27) is more attractive due to the interpretation of its static long-run solution, namely  $E(\Pi \mathbf{z}_t + \delta) = 0$  means the equilibrium of the system.

In the static long-run solution,  $E(\Pi \mathbf{z}_t + \delta) = 0$ ,  $E(\varepsilon_t) = 0$  and  $\Delta \mathbf{z}_t = \Delta \mathbf{z}_{t-k}$  for every  $k$ , thus

$$\Delta \mathbf{z} = \sum_{k=1}^{p-1} \Gamma_k \Delta \mathbf{z} \quad (28)$$

rearrange it

$$(\mathbf{I} - \sum_{k=1}^{p-1} \Gamma_k) \Delta \mathbf{z} = 0 \quad (29)$$

supposing that  $\Delta \mathbf{z} \neq 0$  yields

$$\mathbf{I} - \sum_{k=1}^{p-1} \Gamma_k = 0 \quad (30)$$

which implies:

$$1 = \sum_{k=1}^{p-1} \sum_{j=1}^N \Gamma_{k,i,j} \quad \text{for every } i \text{ where } i \in (1, 2, \dots, N) \quad (31)$$

where  $\Gamma_{k,i,j}$  denotes the  $i$ th (row)  $j$ th (column) element of the  $k$ th  $\Gamma$  matrix, thus  $i$  denotes the  $i$ th equation in VECM. In other words, equation (31) means the sum of short-run parameters should equal one in every equation of VECM.

### A.3 Tables

**Table 1 Estimation results of house price equation**

$$\Delta ph_t = \gamma_1 + \gamma_2(ph_{t-1} + \alpha_1 - \alpha_2 y_{t-1}) + \sum_{i=3}^n \gamma_i \Delta p_{t-(i-2)} + \gamma_{n+1} \Delta y_t$$

Parameters	UK ( $n=4$ )		Hungary ( $n=3$ )
	quarterly	yearly	
$\alpha_1$	-	-	- 3.88
	-	-	(0.008)
$\alpha_2 y_{t-1}$	0.76	0.97	1
	(0.421)	(0.022)	-
$\gamma_1$	-0.15	-0.40	0.00
	(0.183)	(0.128)	(0.002)
$\gamma_2 ECM_{t-1}$	-0.03	-0.25	-0.14
	(0.016)	(0.086)	(0.039)
$\gamma_3 \Delta ph_{t-1}$	0.48	0.48	0.91
	(0.115)	(0.126)	(0.120)
$\gamma_4 \Delta ph_{t-2}$	0.34	-0.22	-
	(0.120)	(0.139)	-
$\gamma_5 \Delta y_{t-1}$	0.10	0.95	0.06
	(0.184)	(0.224)	(0.094)
Adjusted R <sup>2</sup>	0.52	0.50	0.74
LM-SC(2) $p$ value:	0.38	0.36	0.12
ARCH(1) $p$ value	0.42	0.12	0.41
White HET $p$ value	0.63	0.96	0.30
Wald test $p$ value of $\alpha_2 = 1$	0.57	0.23	-
Wald test $p$ value of $\sum \gamma_i = 1$ , $i \geq 3$	0.67	0.28	0.86
$\alpha_1$	-	-	- 3.88
	-	-	(0.008)
$\alpha_2 y_{t-1}$	1	1	1
	-	-	-
$\gamma_1$	-0.23	-0.32	0.00
	(0.110)	(0.108)	(0.001)
$\gamma_2 ECM_{t-1}$	-0.03	-0.17	-0.14
	(0.015)	(0.059)	(0.036)
$\gamma_3 \Delta ph_{t-1}$	0.49	0.46	0.93
	(0.111)	(0.124)	(0.059)
$\gamma_4 \Delta ph_{t-2}$	0.34	-0.28	-
	(0.118)	(0.128)	-
$\gamma_5 \Delta y_{t-1} = (1 - \sum \gamma_i) \Delta y_{t-1}$ , $i \geq 3$	0.172	0.826	0.07
	-	-	-
Adjusted R <sup>2</sup>	0.54	0.51	0.75
LM-SC(2) $p$ value:	0.39	0.27	0.13
ARCH(1) $p$ value	0.42	0.06	0.35
White HET $p$ value	0.59	0.99	0.29

Standard errors are in brackets.

**Table 2 Test for Equality of variances between growth rate of house prices and income**

Method	df	Value	Probability
F-test	(71, 71)	5.75	0.00
Siegel-Tukey		5.19	0.00
Bartlett	1	48.17	0.00
Levene	(1, 142)	32.33	0.00
Brown-Forsythe	(1, 142)	31.54	0.00

where  $\text{var}(P_t/P_{t-1}) = 0.029$  and  $\text{var}(Y_t/Y_{t-1}) = 0.012$

**Table 3 Test for Equality of variances between rate of return on housing and yield on three-month risk-free bond**

Method	df	Value	Probability
F-test	(68, 71)	36.80	0.00
Siegel-Tukey		3.97	0.00
Bartlett	1	154.26	0.00
Levene	(1, 139)	66.93	0.00
Brown-Forsythe	(1, 139)	63.59	0.00

where  $\text{var}(P_t + V_t/P_{t-1}) = 0.026$  and  $\text{var}(r_3) = 0.017$

**Table 4 Granger causality test between the  $\tau$  and  $ER$  in UK**

i = 1		i = 2		i = 3	
lead	lag	lead	lag	lead	lag
0.07	0.37	0.09	0.06	0.07	0.00
i = 4		i = 5		i = 6	
lead	lag	lead	lag	lead	lag
0.01	0.00	0.02	0.01	0.04	0.00

$p$  value of Granger causality test where the lagged and leaded variable is the excess return.

**Table 5 Granger causality test between the  $\tau$  and  $(ER - \overline{ER})^2$  in UK**

i = 1		i = 2		i = 3	
lead	lag	lead	lag	lead	lag
0.76	0.18	0.79	0.27	0.02	0.44
i = 4		i = 5		i = 6	
lead	lag	lead	lag	lead	lag
0.01	0.10	0.02	0.09	0.04	0.15

$p$  value of Granger causality test where the lagged and leaded variable is the squared excess return.

**Table 6 Granger causality test between the  $\tau$  and  $ER$  in Hungary**

i = 1		i = 2		i = 3	
lead	lag	lead	lag	lead	lag
0.00	0.25	0.01	0.44	0.00	0.59
i = 4		i = 5		i = 6	
lead	lag	lead	lag	lead	lag
0.00	0.78	0.01	0.67	0.10	0.25

$p$  value of Granger causality test where the lagged and leaded variable is the excess return.

**Table 7 Estimation result of housing investment ratio in UK**

Parameters	Linear	Logistic
$\eta_1$	0.01 (0.007)	-2.70 (0.049)
$\eta_2$	0.60 (0.125)	3.23 (0.789)
$\eta_3$	0.33 (0.126)	3.05 (0.813)
$\eta_4$	0.13 (0.069)	0.89 (0.477)
$\eta_5$	-3.43 (1.335)	-35.01 (9.458)
Adjusted $R^2$	0.890	0.897
LM-SC(2) $p$ value	0.20	0.20
ARCH(1) $p$ value	0.36	0.82
White HET $p$ value	0.04	0.06
Ramsey RESET Test $p$ value	0.14	-

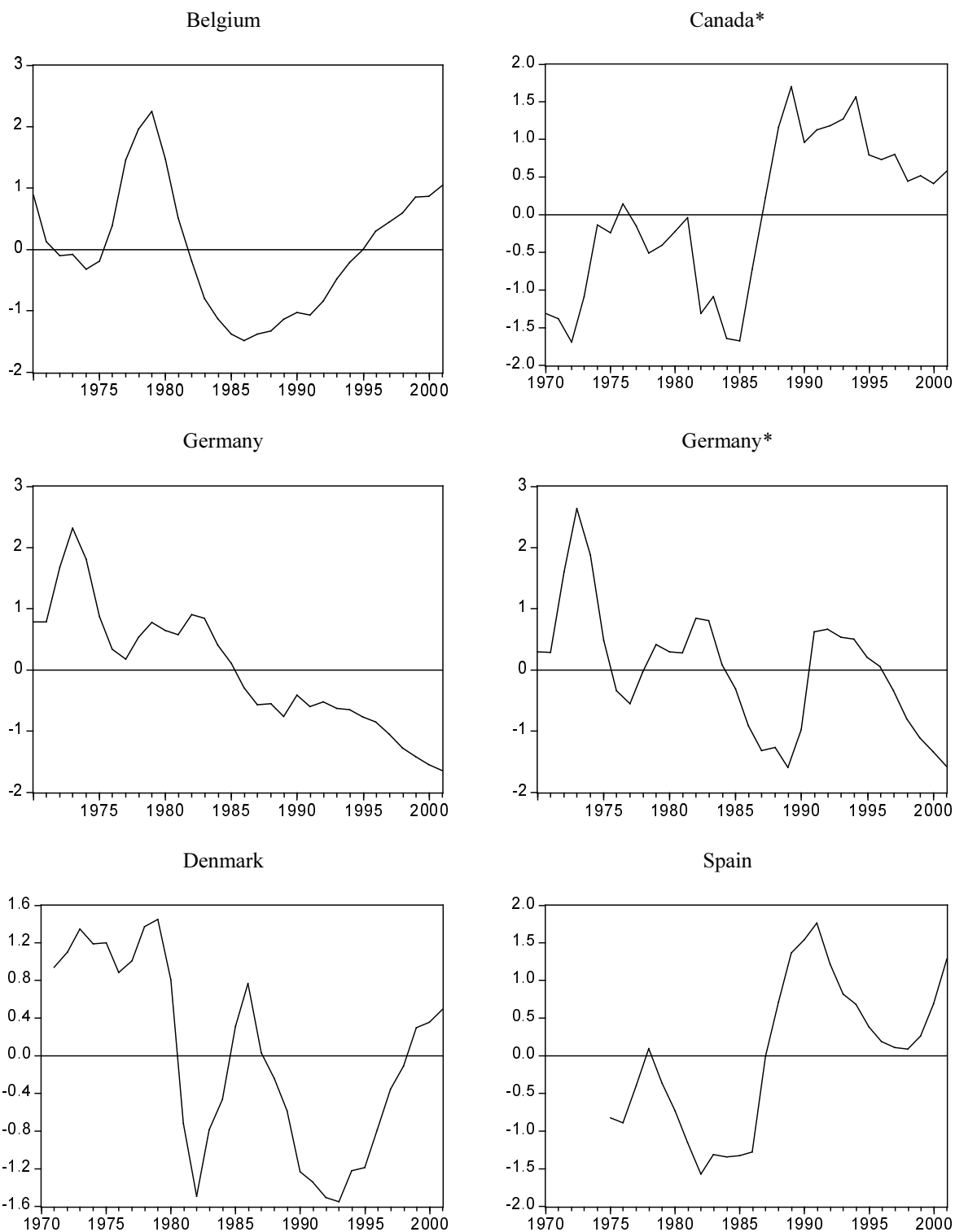
Standard errors are in brackets.

**Table 8 Estimation result of housing investment ratio in Hungary**

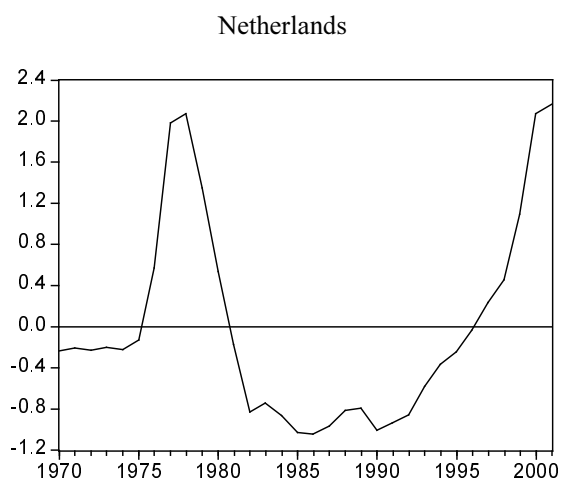
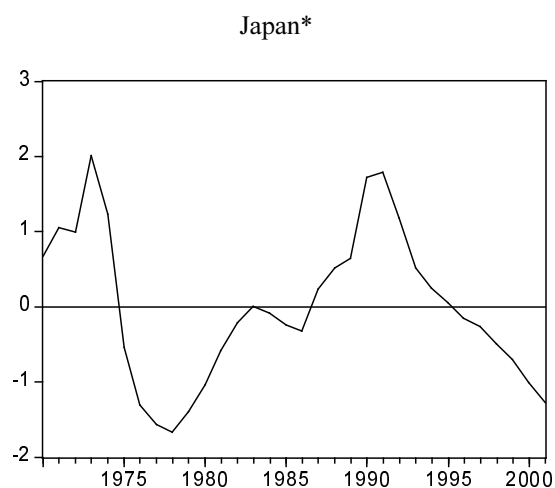
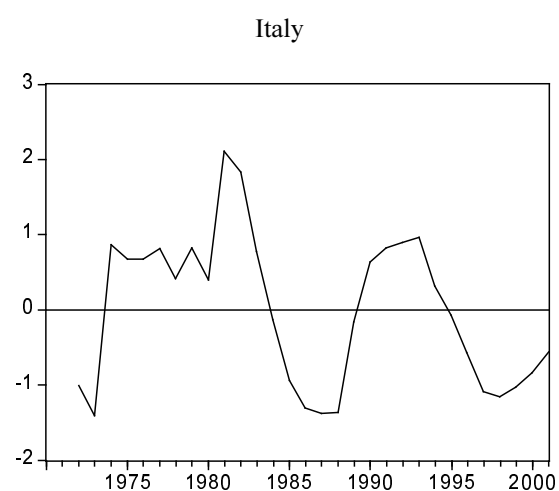
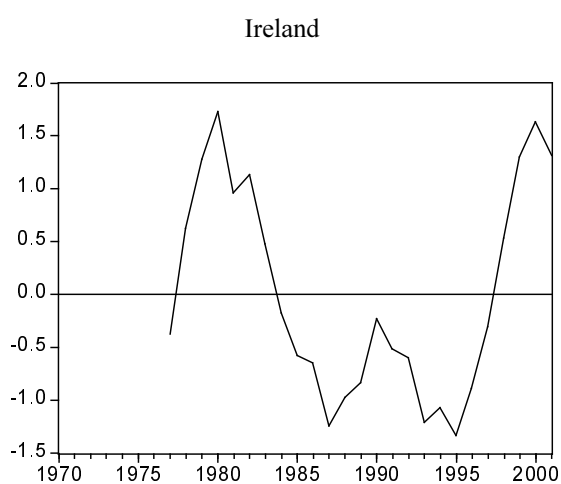
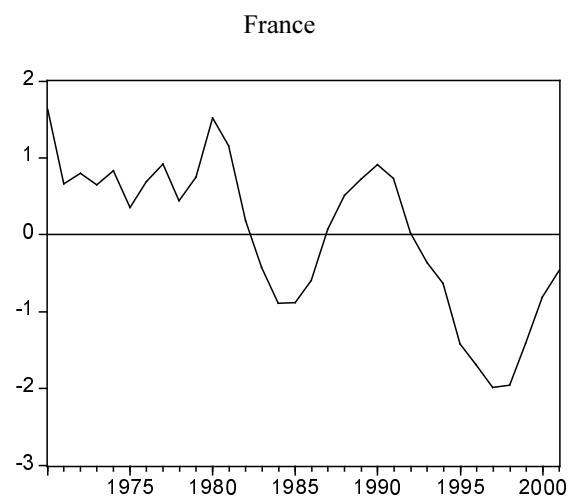
Parameters	Linear	Logistic
$\eta_1$	0.39 (0.014)	-0.44 (0.058)
$\eta_2$	3.23 (1.045)	14.45 (4.779)
$\eta_3$	2.69 (0.952)	11.23 (4.215)
$\eta_4$	0.12 (0.019)	0.49 (0.080)
$\eta_5$	-0.08 (0.024)	-0.34 (0.103)
Adjusted $R^2$	0.836	0.832
LM-SC(2) $p$ value	0.66	0.60
ARCH(1) $p$ value	0.67	0.64
White HET $p$ value	0.94	0.93
Ramsey RESET Test $p$ value	0.70	-

Standard errors are in brackets.

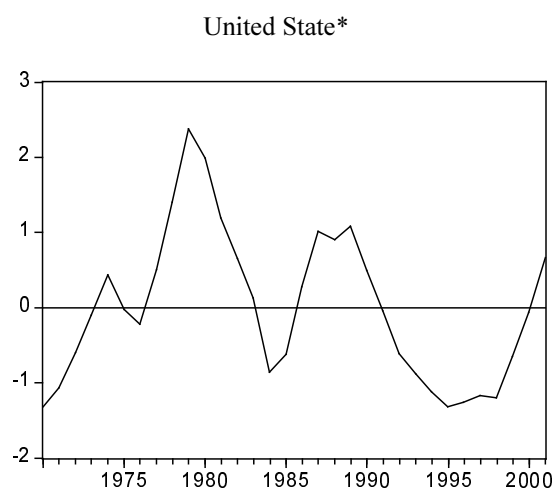
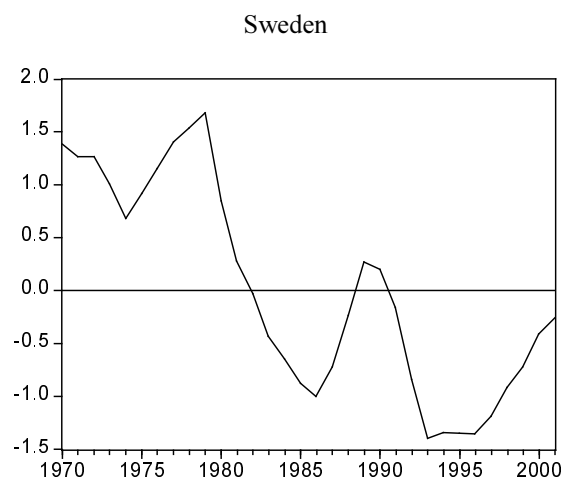
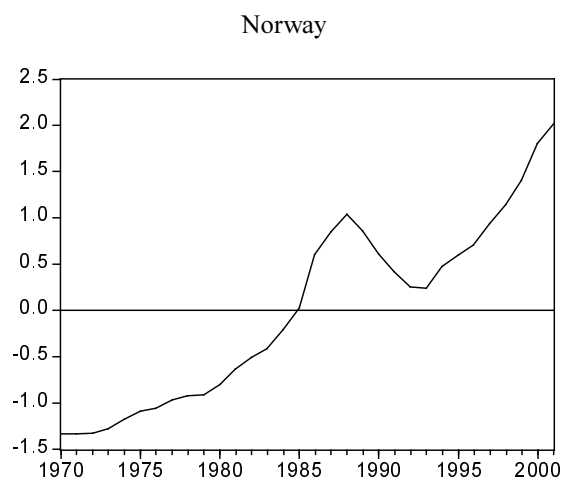
**Chart 7 Ratio of house price to income per capita**



Source: BIS, Eurostat, NIGEM. \*Labour force is used instead of population. The available house prices are published 1995 = 100%, so the absolute value of the ratio is not comparable, thus we normalised it. As a consequence, the charts only display whether the house price ratio to income is stable or not and say nothing about exact ratios and values.



Source: BIS, Eurostat, NIGEM. \*Labour force is used instead of population. The available house prices are published 1995 = 100%, so the absolute value of the ratio is not comparable, thus we normalised it. As a consequence, the charts only display whether the house price ratio to income is stable or not and say nothing about exact ratios and values.



Source: BIS, Eurostat, NIGEM. \*Labour force is used instead of population. The available house prices are published 1995 = 100%, so the absolute value of the ratio is not comparable, thus we normalised it. As a consequence, the charts only display whether the house price ratio to income is stable or not and say nothing about exact ratios and values.

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